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U.S. Energy Flow–1992

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Contents

Abstract

Energy consumption in the United States rose slightly in 1992, reflecting partial recovery from the economic recession that prevailed during the previous year. Increases were registered in all major end use sectors with the largest occurring in the industrial sector. Energy consumed for transportation, which reflects improved passenger fleet efficiencies and a growing population as well as economic activity, returned to 1989–1990 levels.

The United States depended on petroleum for 41% of its energy supply. Imports of crude oil and petroleum products increased to compensate for decline in domestic production. Imports rose to 44% of supply. Average refiner acquisition costs for crude oil for the year were under $20 per barrel, thus similar to costs prevailing in 1991. The year also saw the introduction of new reformulated gasolines at the pump, reflecting mandates of the 1990 Clean Air Act Amendments.

Because domestic production of natural gas was close to 1991's, increased demand was accommodated by larger (16%) imports from Canada. Numerous natural gas pipelines were under construction throughout the country or in the proposal stage. Most of the projects will carry Canadian gas with the largest share destined for California and the Northeast part of the country. Coal production was virtually unchanged from 1991 and thus well below 1990 production. Nonetheless coal supplied about one quarter of U.S. energy needs, primarily for electrical generation.

For the third year electricity transmitted by utilities departed from historic growth trends; it remained at 1991 levels. Reduced use of air conditioners as a consequence of a nationwide cool summer affected electrical consumption; however, other factors such as growth of cogenerators and other self-generators have affected the demand on utilities. Of the fossil fuels used to generate electricity, coal was the most important as it has been for many decades. Oil use to this end has become quantitatively insignificant but vital in special situations. Nuclear power's contribution increased to 22% of total utility generation despite the retirement of several reactors. The drought in the Western sectors of the nation resulted in a smaller contribution from hydroelectric power to the total. Other types of renewable energy used for electric generation made no headway and remained minor contributors.

The Energy Policy Act of 1992 was signed into law in October. Among its many provisions, this act encourages independent power producers to compete with the utilities in wholesale production of electricity, streamlines the licensing of nuclear power plants, promotes the development of renewable energy sources through tax incentives, imposes efficiency standards on many manufacturing items, requires federal and private fleets to buy vehicles that run on alternative fuels, and requires the Secretary of Energy to develop a plan to decrease oil consumption, increase the use of renewable energy, improve conversion efficiencies, and limit the emission of greenhouse gases.

Introduction

United States energy flow charts tracing primary resource supply and end-use have been prepared by members of the Energy Program and Planning groups at the Lawrence Livermore National Laboratory since 1972.[1,2] They are convenient graphical devices to show relative size of energy sources and end-uses since all fuels are compared on a common Btu basis. The amount of detail on a flow chart can vary substantially, and there is some point where complexity begins to interfere with the main objectives of the presentation. The charts shown here have been drawn so as to remain clear and be consistent with assumptions and style used previously.

Energy Flow Charts

Figures 1 and 2 are the U.S. energy flow charts for calendar years 1992 and 1991,[3] respectively. (These charts are included in the centerfold, pages 10 and 11.) The 1992 chart is based on provisional data published by the Energy Information Administration of the Department of Energy.[4] Conventions and conversion factors used in the construction of the charts are given in the Appendix. For comparison with earlier years, consumption of energy resources is given in Table 1.[4,5] These data in many instances contain revisions of data previously reported in this series.

Comparison of 1992 Energy Use with 1991 and Earlier Years

Energy consumption has been relatively stable between 1989 and 1992 (Fig. 3 and Table 1).[4] Historically energy consumption has been strongly influenced by the price (and availability) of petroleum, which remains the nation's largest single energy source. Over the 1989–92 interval the average refiner acquisition cost for oil showed modest fluctuations ($18–22 per barrel) as compared with the gyrations of the previous two decades. The refiner acquisition cost is a weighted average of domestic and imported crude oil. Before the Arab embargo of 1973, oil was approximately $4 a barrel. It rose to an all-time high of $35 per barrel in 1981 and fell from $27 to $14 per barrel in 1986. The consequences of this volatility on consumption are apparent in Fig. 3. However, this is not to say that other factors were not simultaneously at work, e.g., departures from seasonal temperature averages, increase in the population, and economic recessions. Further, although oil has been critical to the U.S. economy for decades, its importance in the total slate of fuels has steadily diminished. In 1973 petroleum use accounted for 46% of total U.S. energy consumption, whereas in 1992 it accounted for 41%.

The increase in total energy consumption in 1992 reflects partial recovery from the recession. The recession particularly affected the industrial sector and thus the manufacturing and construction components of the gross domestic product (Table 2)[6] as opposed to the service component. The latter includes real estate and financial, legal, and health services, etc. Nevertheless, nationwide unemployment worsened slightly in 1992. At year-end it stood at 7.3%, having been impacted by California's unemployment, which increased sharply in 1992 to 9.7% in December.[7] California represents 14–15% of U.S. economic activity and industrial production.

Net energy consumption increased in all sectors with the largest increase (~4%) being registered in the industrial category. The latter was due to increased use of oil and gas, which nonetheless did not reach 1973–4 levels of use. Coal's role in industrial output fell as it has for 16 of the previous 20 years.

Energy used in the residential/commercial sectors increased 1%, and energy used for transportation increased ~2% despite improved automobile fleet averages. Net utility electrical generation declined somewhat for the first time in a decade. The demand in 1992 was influenced by a mild summer as measured by cooling degree-days. It should be noted, however, that utility generation or utility electrical sales do not include the electricity generated and consumed by nonutility self-generators and cogenerators, which is substantial and growing. The amounts used by this group of generators are incompletely monitored.

On the supply side, domestic production of all fossil fuels was close to 1991 levels. Net imports of both natural gas and petroleum rose 10.2 and 4.5%, respectively. Although natural gas imports showed a large percentage increase, in contrast to petroleum they comprise only a small proportion—about 10%—of supply. The amount of energy from

Table 1. Comparison of annual energy use in United States.

	Quads							
	1985	1986	1987	1988	1989	1990	1991	1992
Natural gas production	16.98	16.54	17.14	17.60	17.85	18.36	18.28	18.27
Net imports	0.95	0.75	0.99	1.30	1.39	1.55	1.67	1.84
Crude oil and NGL								
Domestic crude & NGL	21.23	20.53	19.89	19.54	18.28	17.74	18.01	17.55
Foreign imports (incl. products and SPR)	10.61	13.20	14.17	15.75	17.17	17.12	16.35	16.86
Exports	1.67	1.68	1.63	1.74	1.84	1.82	2.13	2.00
SPR storage reserve[a]	0.24	0.11	0.17	0.11	0.12	0.04	–0.10	0.03
Net use (minus exports and SPR)	30.92	32.20	32.87	34.22	34.21	33.55	32.32	32.34
Coal production (incl. exports)	19.33	19.51	20.14	20.74	21.35	22.46	21.59	21.56
Electricity								
Hydroelectric (net)								
Utility	0.96	0.99	0.85	0.76	0.90	0.96	0.94	0.82
Imports	0.41	0.36	0.46	0.32	0.11	0.02	0.23	0.28
Geothermal & other (net)	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Nuclear (gross)	4.15	4.47	4.91	5.66	5.68	6.16	6.58	6.65
Fossil fuel (gross)	18.79	18.59	19.37	20.12	20.54	20.32	20.07	19.97
Gas	3.16	2.69	2.94	2.71	2.87	2.88	2.86	2.83
Coal	14.54	14.44	15.17	15.85	15.99	16.19	16.03	16.19
Oil	1.09	1.45	1.26	1.56	1.69	1.25	1.18	0.95
Total transmitted energy	8.85	8.86	9.25	9.56	9.61	9.60	9.87	9.82
Residential and commercial[b]	14.84	14.79	15.15	16.00	16.26	15.57	15.99	16.16
Industrial[c]	20.52	20.10	21.12	22.09	22.27	22.84	22.57	23.49
Transportation	20.07	20.81	21.44	22.30	22.55	22.53	22.20	22.53
Total consumption[d] (DOE/EIA)	74	74	77	80	81	81	81	82

Source: Monthly Energy Review, U.S. Department of Energy, April 1993; *Annual Energy Review—1992*, U.S. Department of Energy, June 1993.

[a]Strategic petroleum reserve storage began in October 1977.

[b]Excludes electrical losses.

[c]Includes field use of natural gas and non-fuel category and excludes electrical losses.

[d]Note that this total is not the sum of entries above.

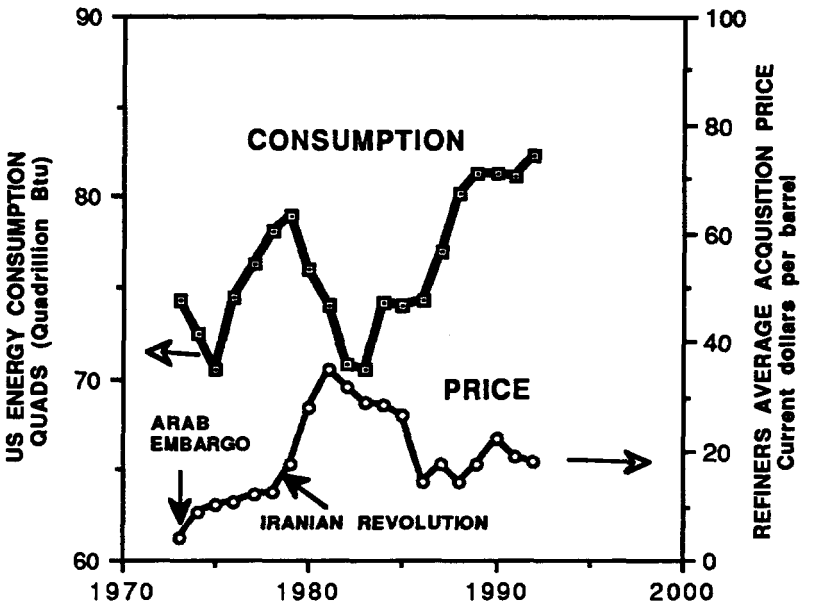


Figure 3. U.S. energy consumption and the price of crude oil.
(Source: Monthly Energy Review, U.S. Department of Energy, April 1993)

renewable sources besides that from hydroelectric power was about the same as in 1992. "Other" includes biomass, wood, waste, geothermal, wind, and solar energy in Department of Energy tallies. The group contributes about 0.3% to the total amount of energy consumed and would contribute much less if geothermal energy, which strictly speaking is not a renewable resource, were not included.

Energy Policy Act of 1992

The long-awaited comprehensive energy bill aimed at curbing U.S. dependence on foreign oil was signed by President Bush in the fall of 1992. Key provisions of the 1300-page bill include:[8]

Table 2. Gross domestic product by major type of product. (Billions of constant 1987 dollars)

	1990	1991	1992
Gross domestic product	4878	4821	4923
Goods	1957	1911	1959
Services	2463	2498	2531
Structures	458	412	432

Source: Survey of Current Business, Table 1.4, 72 (July 1992) and 73 (March 1993).

Note: Totals may not equal the sum of the components because of independent rounding.

• Requires the Secretary of Energy to develop a strategy that promotes energy efficiency and limits the emission of carbon dioxide and other greenhouse gases. The plan will seek to attain a 30% increase in efficiency by 2010, as compared to 1988, and to promote a 75% increase in the use of renewable energy by 2005. It also sets a goal of decreasing oil consumption from 40% of total energy consumption to 35% by the year 2005.

• Calls for states to develop building codes and for banks to develop mortgages that promote energy efficiency.

• Establishes new energy efficiency standards for lights, electric motors, shower heads, appliances, and other products.

• Requires federal and private fleets to buy more vehicles that run on alternative fuels (alcohols, natural gas, liquefied petroleum gas, hydrogen, coal-derived liquid fuels, electricity, etc.). Also provides for tax incentives for the purchase of alternative-fueled vehicles ($2000 per car with a 25% per year reduction in the incentive starting in 2002) or electric vehicles (10% tax credit, to be phased out beginning in 2001 and ending in 2005).

• Creates a program to demonstrate the viability of vehicles that run solely or in part on electricity with costs split with private industry.

• Provides tax incentives for development of renewable energy sources (1.5 cents per kilowatt hour for 10 years for new sources).

• Promotes non-fuel use of coal, coal refining technologies to reduce emissions, the development of coal-based transportation fuels, and further demonstration of underground coal gasification and thus continues the Department of Energy's Clean Coal Technology program that was scheduled to end in 1993.

• Encourages independent power producers to compete with utilities in the *wholesale* production of electricity and orders utilities to transmit their power.

• Authorizes the expansion of the U.S. Strategic Petroleum Reserve to 1 billion barrels and makes it easier to use the reserves to counter sharp price increases caused by supply interruptions.

• Turns the government's uranium enrichment program over to the private sector.

• Removes restrictions on importation of Canadian natural gas.

• Streamlines the licensing of commercial nuclear power plants, allowing a single permit for construction and operation.

• Authorizes funding of a private research-and-development program to develop commercial advanced reactors, with 1996 as the target date for approving a standardized design.

• Requires the Environmental Protection Agency to issue new public health and safety standards for a proposed high-level nuclear waste repository at Yucca Mountain, NV, following a National Academy of Sciences study of the issue.

• Provides tax relief under the Alternative Minimum Tax statutes to *independent* oil and gas drillers.

The legislation does not address the first priority of environmental groups—increasing automobile fuel efficiency standards—nor does it directly deal with ever-declining U.S. domestic oil and gas production and increasing imports. The assumption appears to be that the latter problems will become unimportant as alternative fuels and vehicles come into the marketplace and find wide acceptance. Not surprisingly, the oil industry is not as sanguine and believes that it is an overestimation of the rate at which alternative fuels will become viable competitors to gasoline.[9]

Supply and Demand of Fossil Fuels

Oil Supply

Domestic Production

Crude oil production in the United States declined for the eighth year (Fig. 4). All indicators of activity within the petroleum industry showed a substantial downturn: the number of producing wells; the number of stripper wells operating (those producing up to 10 barrels of oil per day); the number of wells drilled; the number of drilling rigs in operation; the average production per well, which is now about 11 barrels per day, down from 17.2 barrels per day in 1970; and the number of people employed in the United States.[10] The U.S. Bureau of Labor Statistics estimates that almost 500,000 jobs have been cut from the industry over the past 10 years.[11]

The production decline is attributed both to low crude prices (Fig. 4) precipitated in 1986 by a surge in Saudi Arabian oil production when the country ceased to constrain its output under the OPEC quota system and to general depletion of the U.S. resource. High crude oil prices in the early 1980s had arrested U.S. production decline by promoting wildcat drilling, in-fill drilling, and enhanced recovery projects; however, loss of that incentive resulted in a return to the former state of slow decline as additions to reserves through development and discovery failed to keep pace with production. To a degree the decline in U.S. activity can be reversed; however, reactivation of low production wells, which are being abandoned at the rate of 17,000 per year,[9] is difficult if not impossible.

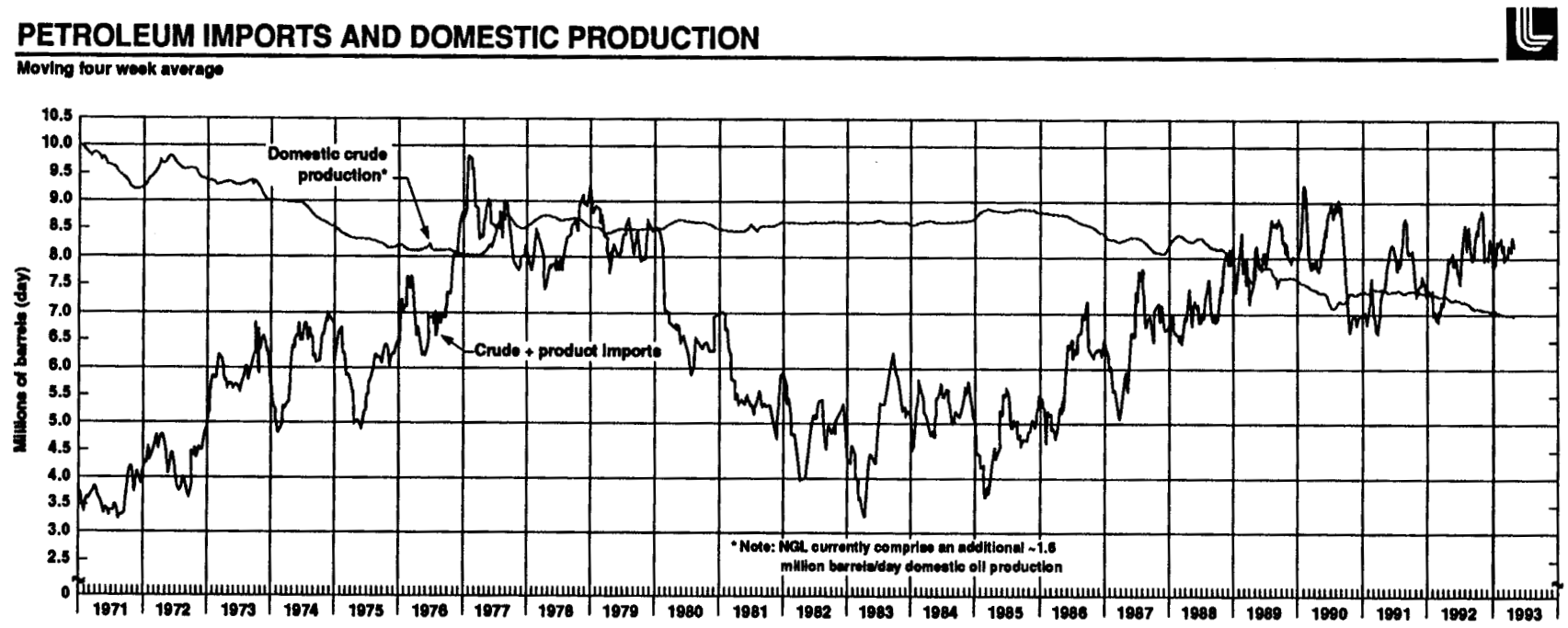
Alaskan oil production, which has comprised one quarter of U.S. crude oil production since the super-giant Prudhoe Bay field on the North Slope reached full production, also fell in 1992. The field started its decline in 1989. Despite gigantic gas injection projects and hydraulic fracturing operations, which have boosted the amount of oil ultimately to be recovered, production is anticipated to continue to fall at the rate of 10% per year.[12]

One bright spot in an otherwise lackluster year for the oil industry was progress in the decade-long effort to bring the Point Arguello, CA, offshore oil field on line. The field owned by Chevron and its partners is the largest field discovered since Alaska's Prudhoe Bay. The owners, who had proposed to transport the oil produced from the offshore platforms by tanker to Los Angeles refineries until a pipeline was built, had been at a 3-year impasse with Santa Barbara County officials who rejected the interim solution and insisted that all the oil produced be piped to shore. Starting in mid-1991 existing pipelines were used to transport about half of the 100,000-barrel-per-day potential to shore and hence to Chevron's northern California refinery. There half is refined, and ironically the remainder is shipped by tanker to Los Angeles refineries transiting the Santa Barbara County coast.[13] At year's end the California Coastal Commission indicated that it would approve an interim tanker permit, albeit with restrictive conditions that include a time limit on tanker transport from the offshore field.

Major U.S. companies have increasingly concentrated their exploration efforts overseas as (1) prospects in federal OCS (Outer Continental Shelf) leases in Alaska have dimmed, e.g., the Bering Sea basins and the Chukchi and Beaufort Seas, and (2) promising areas such as the Arctic National Wildlife Refuge, Alaska, and the Pacific OCS remain off limits for exploration. Investment in international operations by the industry in 1992 was more than double the investment in the United States by the major and independent companies combined according to a study by Salomon Brothers, Inc., NY.[14]

Oil Imports

Net import of crude oil and petroleum products increased several percent in 1992 and was the source of 45% of U.S. petroleum supply.[15] The increase in net oil imports



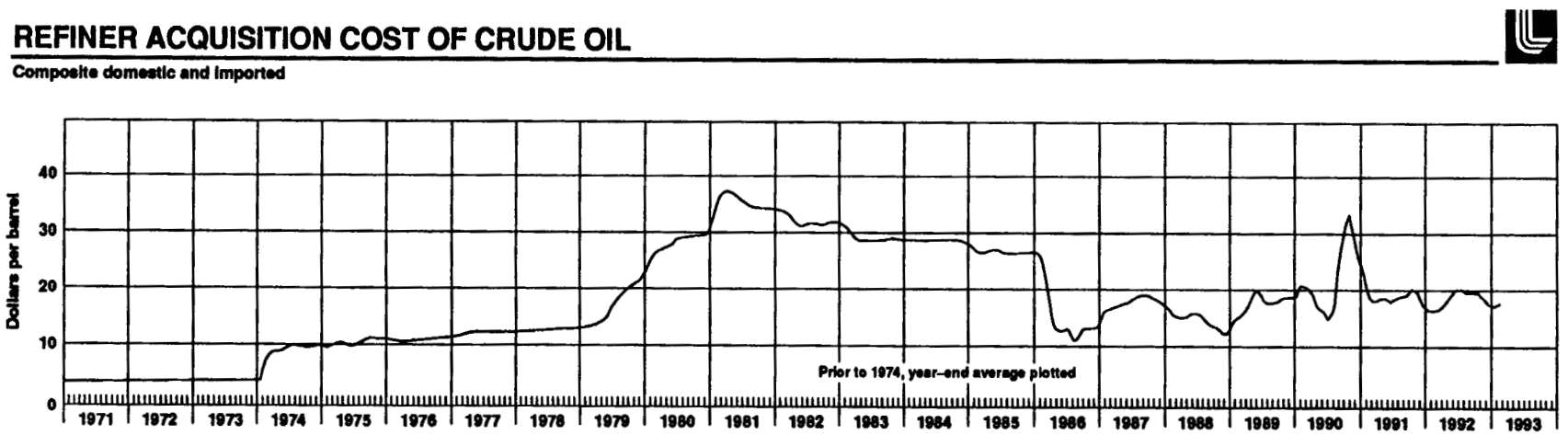


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Figure 4. Petroleum imports and domestic production; refiner acquisition cost of crude oil.

followed two years of decline in keeping with a general fall in petroleum consumption during the economic recession. However, imports of petroleum products as opposed to imports of crude oil declined for the fourth straight year due largely to declining imports of residual oil.

Saudi Arabia remained the largest single supplier (22%), followed by Venezuela (15%) and Canada (13.5%). Although Kuwaiti oil production by December 1992 had returned to near record highs,[16] only a small amount was exported to the United States. Historically Kuwait's oil exports have been principally to Japan and Europe.

The average refiner acquisition cost of crude oil rose to and remained at approximately $20 per barrel in the last half of the year and thus remained well below the all-time highs of $35 per barrel recorded in 1981 (Fig. 4). Not surprisingly, the trade deficit in that year was largely due to record costs associated with the import of crude oil and petroleum products (Fig. 5). In subsequent years, although oil imports have shown a general upward trend, falling oil prices have stabilized oil's absolute contribution to the trade deficit. The latter has nonetheless deepened appreciably (Fig. 5). Clearly the U.S. merchandise trade imbalance has been affected almost as severely by imports of manufactured items (such as automobiles, engines and parts) as by imports of oil.[17]

Oil Demand

In 1992 oil consumption rebounded from that of the previous year; however, it did not reach 1988–1990 levels. Although effects of the economic recession were still apparent in 1992, they were not as profound as in 1991.

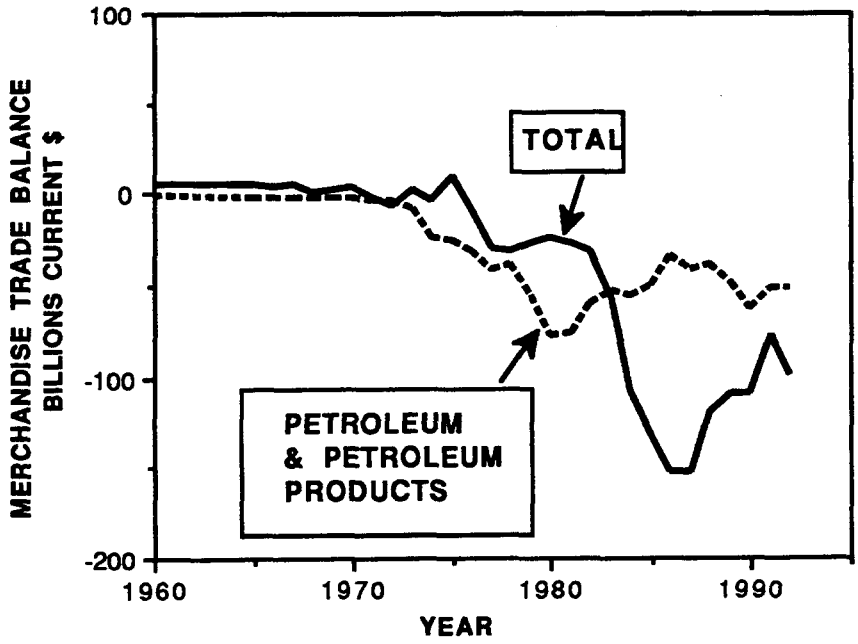

Figure 5. Oil imports contribution to the U.S. merchandise trade deficit. *(Source: Statistical Abstract of the US 1992,* U.S. Department of Commerce, Bureau of the Census, Washington, DC, Table 1330 [1992]; *Survey of Current Business,* U.S. Department of Commerce Table 4.3 [March 1992 and March 1993].)

Transportation is the principal consumer of petroleum products in the United States (Fig. 1). Improved highway mileage for passenger cars continues to make in-roads into gasoline usage, and hence oil consumption, as older cars are retired. The savings are countered to some degree by annual increases in the number of automobiles on the roads and the number of miles driven. On balance, use of gasoline increased by a small amount; however, other transportation fuels—jet fuels and residual fuel oil used as a vessel bunkering fuel—declined.

The average passenger car mileage for 1991, the last year for which data are available, is 21.68 miles per gallon.[4] The CAFE (Corporate Average Fuel Economy) standard that took effect in 1978 remained at 27.5 miles per gallon in 1992, and proposals to raise it to 40 miles per gallon at some time in the future did not survive in the Energy Policy Act passed during the year. The arguments against the higher standards revolve around loss of jobs in the domestic automobile industry, since the standards would require additional retooling that the ailing industry believes it is financially unable to do in the near term.[18]

All the major automobile manufacturers in the United States are in the process of developing an electric vehicle whose debut is planned at the end of the decade.[19,20] The R&D is driven by California's 1990 adoption of the world's toughest automobile emission standards, which require that 2% of all cars sold in the state (or about 40,000) be emissions-free starting in 1998; the percentage increases to 10% by 2003. At least 15 other states have adopted or are considering adopting similar regulations. Concern is that Japanese car makers may reach the marketplace before U.S. manufacturers.

At the end of the year gasoline prices in many parts of the country increased up to 5 cents per gallon as oxygenated gasoline, which lowers the emissions of carbon monoxide, went on sale.[21] The new reformulated gasolines are the result of standards mandated by the 1990 Clean Air Act Amendments. Initially the standards affect regions of the country that experience carbon monoxide problems during winter months; however, by 1995 areas not now meeting ozone standards will be included as well.

The increase in demand for distillate (heating) oil and natural gas within the residential and commercial sectors can be traced to an uncommonly cold winter in the Northeast and Midwest following on several relatively mild winters.[22]

Natural Gas Supply

Domestic natural gas production was unchanged from 1991; however, imports principally from Canada increased 16% (Fig. 6).[4] By region, 42% of Canadian gas exports go the Midwest, 23% to California, 21% to the Northeast, 12% to the Pacific Northwest, and 2% to the Mountain Region.[23]

The average wellhead price fell from an all-time high of $2.66 per thousand cubic feet in 1984 to $1.85 in 1992, which was 10% higher than the average in 1991.[4] Import prices followed the same trends, having fallen from $4.08 to $1.96 in the same time span. Prices paid by small customers in the residential and commercial sectors nationwide incompletely reflected these substantial drops in wellhead and imported gas prices; average prices for these users fell from $6.12 to $5.85 per thousand cubic feet (residential) and $5.55 to $4.86 per thousand cubic feet (commercial) between 1984 and 1992. On the other hand prices to industrial customers and electric utilities fell by about a third: from $4.22 to $2.79 and from $3.70 to $2.37 per thousand cubic feet, respectively.

Depressed wellhead natural gas prices following the international break in crude oil prices have sharply curtailed exploration activity in the United States. The number of

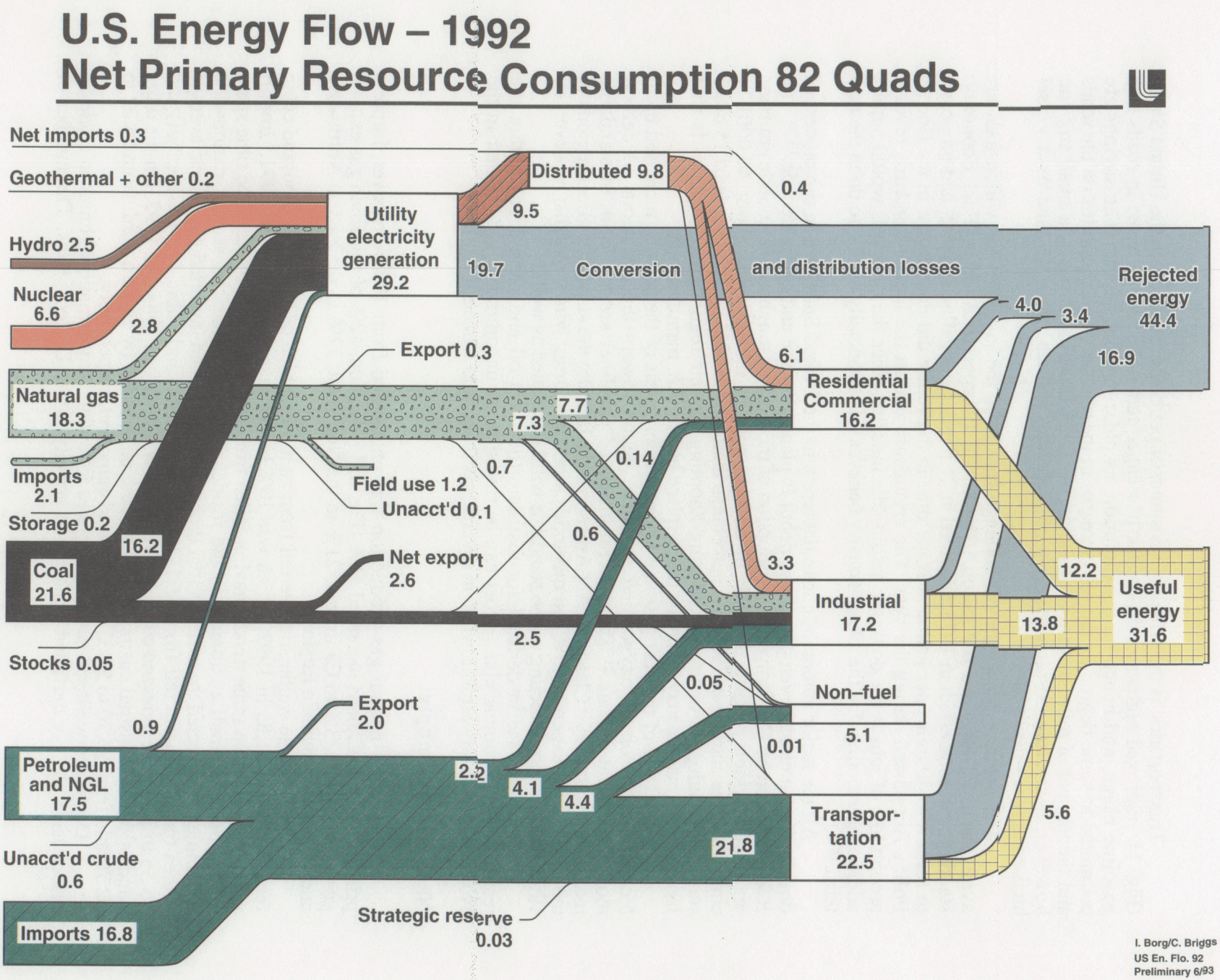

Figure 1. U.S. Energy Flow—1992, in quads. (One quad equals one quadrillion Btu.)

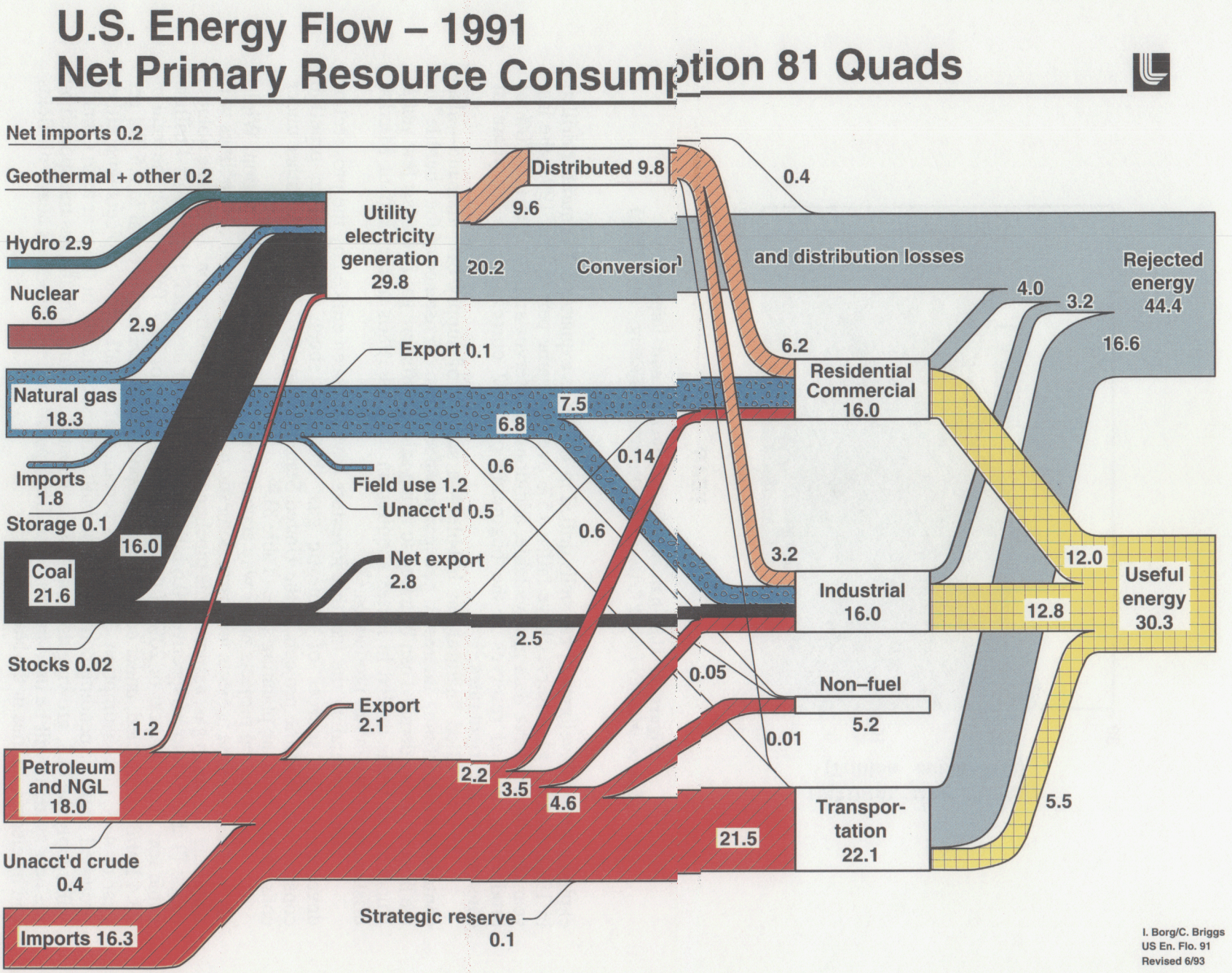

Figure 2. U.S. Energy Flow—1991, in quads.

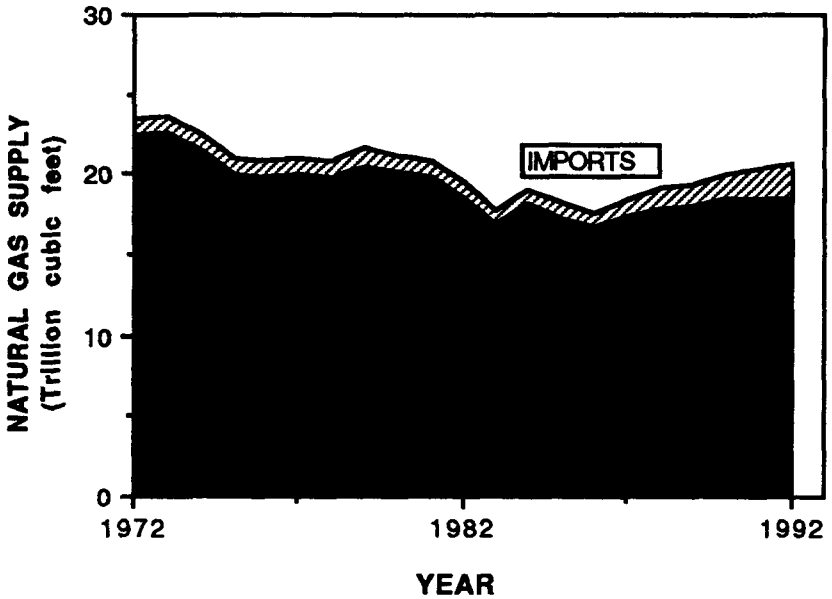

Figure 6. U.S. natural gas production and imports.
(Source: Monthly Energy Review, U.S. Department of Energy, April 1993.)

exploratory and development gas wells drilled in 1992 was a quarter of the number drilled in 1984. Natural gas reserves have fallen 15% over the same period.[24] In 1991, the last year for which reserve data are available, additions to reserves amounted to just 70% of production. Proved reserves at the beginning of 1992 correspond to 8.5 years of consumption at current rates.[24]

The so-called "natural gas bubble"—a surplus of supply over demand—also contributed to declining interest in new gas prospects. The persistence of the "bubble" in the light of strong demand can be traced to rising sales of offshore gas in the last few years. Hundreds of wells drilled in leases acquired in the mid-1980s in the Gulf of Mexico offshore areas are in full production.[25]

Notwithstanding the fact that investors have not been enticed by the prospect of developing new sources of domestic gas, they have been interested in pipeline construction. Pipeline projects in the United States totaling $12 billion are either under construction or in the planning stage (Table 3).[26]

Construction projects under way account for almost half of the $12 billion. While

Table 3. U.S. natural gas pipeline construction projects.

Region	Capacity (Bcf/d) Completed or under construction	Proposed/ Pending	$ (billion)
California	3.14	2.61	4.72
Northeast	2.39	2.42	2.85
Arkoma basin, OK	0.44	1.16	0.54
Mobile Bay, AL	0.60	0.36	0.06
San Juan basin, NM, CO	1.86	0.71	0.38
Rocky Mts.	0.67	0.86	0.82
Louisiana/Mississippi	–	1.25	0.32
Midwest	0.56	–	0.17
Mexico	0.46	2.31	0.26
South Atlantic	0.49	0.15	0.32
Florida	–	0.92	1.60
Total	**10.61**	**12.76**	**12.03**

Source: B. White, *Gas Energy Review*, American Gas Association, March 1993.

Note: Totals may not equal the sum of the components because of independent rounding.

Natural Gas Demand

Annual natural gas consumption increased 3% in 1992, thereby equaling consumption levels prevalent in the late 1970s.[4] While use in all end-use sectors increased except the electric utilities, industrial customers registered the largest increases due to fuel switching in enhanced oil production and to the growth of industrial cogeneration operations. Cogenerators purchased more than half of the gas directly from producers and took delivery from third-party transporters.[27] Forecasts predict that industrial consumption of gas may increase 40% by 2005 due in large part to these two activities.[28]

It is also predicted that anticipated increased electrical demand in the United States will result in a large increase in the use of gas by the electrical utilities (150% by 2005 by some accounts, assuming prices do not rise dramatically[29]). Between passage of the Fuel Use Act in 1978 and the year 1988, Congress banned gas as a fuel source for new industrial plants and new electric power plants because of fears of shortages.[30] In subsequent years natural gas has been the preferred fuel for small electric power plants because the small size of natural gas generators mitigates for short construction times and hence lower costs and because use of the fuel does not pose serious pollution problems. The Clean Air Act Amendments of 1990, which ordered sulfur emissions at electric power plants reduced by the year 2000, has also improved the demand for gas as a substitute for coal.

In an era of rising oil imports and trade deficits and enhanced concern about the environment or the planet, natural gas has become an elixir for policymakers, federal and state administrations, and environmentalists. While groping for interim solutions, presumably until acceptable long-term solutions are in hand, there has been concern about even the short-term availability of natural gas to meet growing demand. Thus, numerous studies have been undertaken. For example, the National Petroleum Council, an advisory body to the Secretary of Energy, completed a lengthy study in 1992.[31] It concluded that there is a large untapped domestic resource base that can be developed, albeit at greater cost

than currently developed gas fields. The group concluded that technology and efficiency improvments would tend to mitigate the increasing cost of developing the more expensive supplies and recommended that regulators exercise restraint during expected periods of price and supply volatility as the resource comes into the marketplace.

Coal Supply and Demand

The use of coal in the United States has steadily increased for decades, and 1992 was no exception. The same is true for the world as a whole.[32] Coal is the principal fuel for electrical production in the United States, where it accounts for 55% of electric utility net generation of electricity (Fig. 1).[4] Ironically oil- and gas-rich Texas is the nation's largest coal user. Coal produced 43% of Texas' electricity in 1992; whereas it produced none in 1970. Coal's continued dominance in the electric-generating sector relates to acceptance among electric utilities that it is the cheapest fossil fuel available, despite the high costs of pollution abatement equipment (sulfur scrubbers), and to its assured supply on long-term contracts with stable prices. In 1992 coal was available in long-term electric utility contracts on average at $1.41 per million Btu as compared to $2.55 and $2.33 per million Btu for petroleum and natural gas, respectively.[4] U.S. coal reserves and undeveloped resources are sufficient to last hundreds of years at present rates of use. The Department of Energy annually spends half a billion dollars for research on ways to burn coal cleanly and to utilize the fossil fuel in unique ways.

Despite the several Clean Air Acts passed starting in 1970 and despite the loss of its largest industrial customer (the steel industry, whose use of coking coal has fallen two-thirds in 20 years), the coal industry has remained robust. The Clean Air Act Amendments of 1990 did not address emissions of carbon dioxide, which in the eyes of many is coal's most serious pollutant. Critics concerned with global warming point out that combustion of coal releases about 75% as much carbon dioxide as combustion of natural gas on an equivalent-energy basis. Environmentalists claim "Coal is a fundamental threat to life on this planet. We'll eventually have a fight over every coal-powered electric plant."[33] They deplore the increased use of coal in the United States and in the world as a whole. Nonetheless coal remains the first fuel of choice for large-scale electric generation on economic grounds and may remain so in the future if prices for natural gas and oil increase faster than those for coal. It is reported that 54 large electric power plants currently in the design stage will be coal-fired.[33]

Electrical Supply and Demand

For the first time in a decade, net generation of electricity by utilities fell (1%). A generally cooler summer affected consumption in all end-use sectors but especially residential customers whose usage as judged by sales declined 2.5%. Utility sales to industrial customers rose several percent, and since the sector includes a growing number of self-generators and cogenerators, those sales are an underestimate of the increase in industrial use of electricity in 1992.

Most nonutility generators operate "qualified facilities" as defined by the provisions of the Public Utilities Regulatory Policy Act of 1978 (PURPA), i.e., they produce both electric energy and another form of energy such as heat or steam using the same fuel source, or they are small power producers using waste, geothermal energy, or renewable energy as their energy source. Of nonutility generators, three-quarters are cogenerators whose fuel of choice is natural gas.[34] The combined nameplate capacity of nonutility generators was 48 GWe in 1991, compared to 740 GWe for all classes of utility generators. Nonutility generators represent about 9% of total electricity generation, an increase from 4% in 1985.[35] One-half of U.S. nonutility generating capacity is located in Texas and California. In Texas cogeneration within the chemical industry accounts for most

nonutility generation, and in California nonutilities are primarily small power producers with no cogeneration capability.

The growth of nonutilities can be traced to economic and technological changes going back to the 1960s and to Congressional acts such as PURPA, the Clean Air Acts,

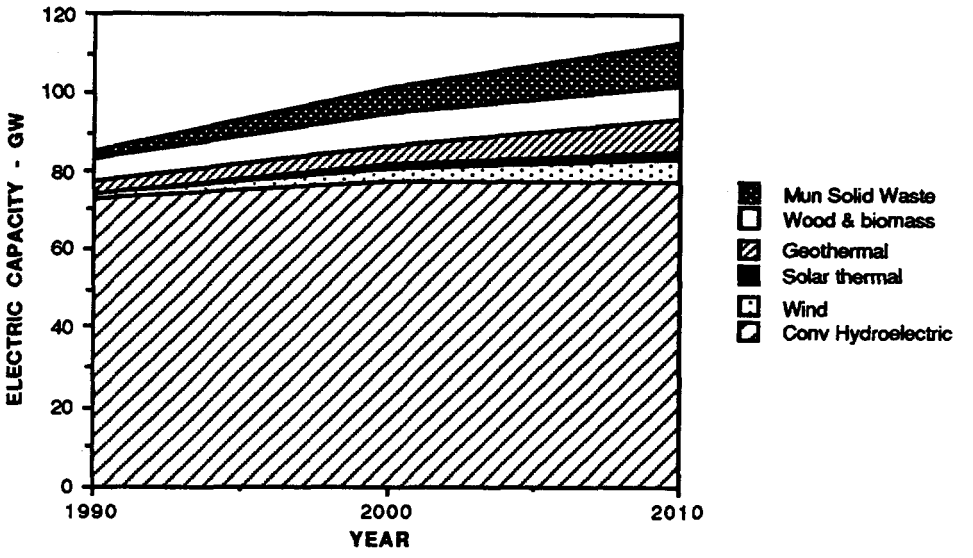

Figure 7. Projections of electric capacity based on the use of renewable resources by utility and nonutility generators. *(Source: Renewable Resources in the U.S. Electricity Supply,* U.S. Department of Energy, February 1993.)

capacity factors for the year 1995 vary from 21% for wind and solar thermal to 72% for biomass and other waste fuels assuming operational and technological improvements.

Figure 7 represents the most recent Department of Energy projections of the role of renewables in the slate of fuels used for electric generation. Note that photovoltaic generation does not contribute to the total by the year 2010.

Nuclear Power

For the first time in more than a decade the number of operable nuclear power plants in the United States declined; nonetheless the net generation of electricity from nuclear power reached an all-time high. An overall small increase in average capacity factors (Table 5)[4] for the nation's 109 reactors more than compensated for the retirement of Yankee Rowe 1 (185 MWe) in Massachusetts and San Onofre 1 (436 MWe) in California. Yankee Rowe 1 was the oldest commercial reactor operating in the United States, having begun commercial operation in July 1961. Among plants with gross output greater than 100 MWe, San Onofre I, CA, and Haddam Neck, CT, are the next oldest; both started commercial operation in January 1968.[37] The need for expensive repairs triggered the decisions to retire Yankee Rowe and San Onofre 1; in the case of Yankee Rowe, metal embrittlement of the reactor vessel raised safety issues,[38] and for San Onofre 1 long use of salt water for cooling had taken its toll on the steam generating system.[39]

At year end there were eight domestic nuclear generating units in some stage of construction. Of these, only four (Comanche Peak 2, TX; Watts Bar, TN; and Bellefonte 1 and 2, AL) are likely to come on line before the end of the century. The remainder have "indefinitely deferred" status.

Table 5. Electrical generation from nuclear power.

	Year			
	1989	1990	1991	1992
Total utility electrical generation (bn kWh)	2784	2808	2825	2796
Nuclear contribution (bn kWh)	529	577	613	619
Percent nuclear	19.0	20.6	21.7	22.1
Installed nuclear capacity[a] (GWe)	98.1	99.6	99.6	99.0
Number of operable reactors	110	111	111	109
Annual nuclear capacity factor (%)	62.2	66.0	70.2	70.9

Source: Monthly Energy Review, U.S. Department of Energy, April 1993.

[a]Net summer capability of operable reactors

The Energy Policy Act passed by Congress in the fall of 1992 includes a provision for streamlining the licensing of commercial nuclear power plants by allowing a "one stop" permit for construction and operation. It was aimed at reducing the financial risks associated with construction of nuclear plants by essentially making it all but impossible for opponents to delay or kill a plant by objections raised after the plants were finished as was done in the case of the Shoreham, NY, and Seabrook, NH, nuclear reactors. The one-step licensing allows the Nuclear Regulatory Commission to grant construction and operating permits at the same time. Although passage of the Energy Policy Act of 1992 containing the new provisions was considered a great victory by the nuclear industry, no new plants are on order or even in the proposal stage; further, the credit-rating agencies remain wary of financing nuclear plants. Mounting maintenance costs, uncertainties concerning radioactive waste disposal, expenses associated with decommissioning closed plants, and finally the litigation that nuclear plants attract pose large financial risks not associated with conventional fossil electrical generating units.

Therefore many utilities continue to look to natural gas electrical generators to fill interim needs. The Sacramento Municipal Utilities District in California, owners of the Rancho Seco nuclear power plant shut down by referendum in 1989, ordered four gas-fired turbines (500 MWe) in 1992;[40] the Long Island Power Authority in New York, which built the ill-fated Shoreham nuclear plant that never operated commercially, entertained bids in 1992 to convert the plant to a gas-fired unit;[41] Public Service of Colorado plans to repower their Fort St. Vrain nuclear plant with natural gas after decommissioning and dismantling the plant, which was retired in 1989.[42] Similar conversions are likely in the future as many aging plants are retired as an alternative to undertaking extensive repairs. Almost half of the operating nuclear plants in the United States are more than 15 years old, and 12 are between 20 and 25 years old.[43]

The arguments for the use of gas for electrical generation are persuasive: the fuel is currently relatively inexpensive and pollution free, and in the near term the supply is assured; the generating units are small and can be brought on line quickly; they do not involve large capital investments; and finally the plants find broad public acceptance, the only dissidents being those environmentalists who believe that wind or solar power is the preferred alternative to fossil fuels for electrical generation.

Thus the future of nuclear power in the United States remains murky despite the changes in the regulatory licensing process, which will cut delays and hence costs, and despite designs for smaller and improved reactors that are under active development. John F. Ahearne, former deputy assistant secretary of energy* and former Chairman of the Nuclear Regulatory Agency, opines "Even with new reactor designs, there is no sign of interest among utilities. That will not develop until the demand for electricity increases and reactors are an economical choice."[44]

Nonetheless foreign orders for nuclear reactors have kept U.S. designers active. Early in 1992 General Electric Co. won approval from Japanese regulators to begin construction of two 1356-MW advanced boiling water reactors northwest of Tokyo.[45] These plants represent the first orders for new nuclear plants that General Electric has received since 1975.

For almost a decade the Secretary of Energy has annually declared the U.S. uranium industry to be nonviable.[46] It has been a victim of low prices and increasing foreign competition, most recently from the former Soviet Union. More than half of domestic production of uranium is now a by-product of the phosphate mining industry; the remainder comes from solution *(in-situ)* mining and mine water recovery, with only 7% from conventional mining. Production from all sources is slightly greater than in 1954 when the domestic industry was in its infancy. At the end of 1992 the last of the United States's processing mills closed.

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Appendix

Data and Conventions Used in Construction of Energy Flow Charts

Data for the flow chart were provided by tables in the Department of Energy/Energy Information Agency's *Monthly Energy Review,*[4] the *Quarterly Coal Report,*[47] and the *Annual Energy Review—1992.*[5]

The residential and commercial sector consists of housing units, non-manufacturing business establishments, health and education institutions, and government office buildings. The industrial sector is made up of construction, manufacturing, agriculture, and mining establishments. The transportation sector combines private and public passenger and freight transportation and government transportation including military operations.

Utility electricity generation includes power sold by both privately and publicly owned companies. The non-fuel category of end-use consists of fuels that are not burned to produce heat, e.g., asphalt, road oil, petrochemical feed stocks such as ethane, liquid petroleum gases, lubricants, petroleum coke, waxes, carbon black, and crude tar. Coking coal traditionally is not included.

The division between "useful" and "rejected" energy is arbitrary and depends on assumed efficiencies of conversion processes. In the residential and commercial end-use sectors, a 75% efficiency is assumed, which is a weighted average between space heating at approximately 60% and electrical lighting and other electrical uses at about 90%. Eighty percent efficiency is assumed in the industrial end-use sector and 25% in transportation. The latter percent corresponds to the approximate efficiency of the internal combustion engine.

There are some minor differences between the total energy consumption shown here in the energy flow charts (Figs. 1 and 2) and the DOE/EIA totals given in Table 1. The industrial consumption total in Table 1 agrees with DOE's *net* industrial total. Both totals include natural gas lease and plant fuel and non-fuel ("non-energy") use, which are shown separately in the flow charts.

Conversion Factors

The energy content of fuels varies. Some approximate, rounded conversion factors, useful for estimation, are given below.

Fuel	Energy content (Btu)
Short ton of coal	22,400,000
Barrel (42 gallons) of crude oil	5,800,000
Cubic foot of natural gas	1,000
Kilowatt hour of electricity	3,400

More detailed conversion factors are given in the Department of Energy's *Monthly Energy Review.*

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